

Gasoline Engine Turbocharging & Rightsizing

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California Air Resource Board
Technology Assessment Workshop
CO₂ Emission Reduction - Cost & Feasibility Analysis
Climate Change Emissions - Light Duty Vehicles
Sacramento, CA
April 20, 2004

Benefits/feasibility (% CO₂ Reduction)

- Over 12 years of production data
- Methodical comparison by world class experts
- Experiments on two US SUVs

Cost

- Direct approach to rightsizing
- Engine family rationalization

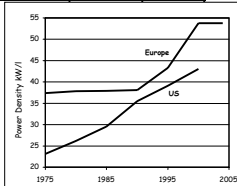
Customer Acceptance

- Turbo gasoline in Europe
- European turbo gasoline imports in the US

Engine	2.2L L4	3.0L V6	3.4L V6	3.3L V6	5.3L V8
Cam/Valve	DOHC 4V	DOHC 4V	DOHC 4V	OHV 2V	OHV 2V
Vehicle	Cavalier	Taurus	Tacoma	Town & C	Sierra
0-60 mph (sec)	8.08	7.24	9.23	9.18	7.97
Curb Weight	2762	3380	3714	3980	4826
Power kW	109	154	140	149	213
** (L)	1.8	2.6	2.3	2.5	3.6

** State of the Art European Engine - Production Vehicle/Engine Data

- Baseline engines oversized compared to European average
- Potential rightsizing by using state of the art
- MAJOR rightsizing by TURBOCHARGING



Technology in Use in Europe

Production vehicle data from 1992 to 2004

5-12% CO₂ Reduction

Methodical, comparison by world class experts

15-21%

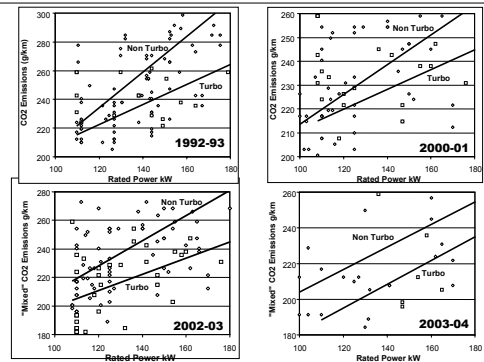
Experimental US SUVs

5-18%

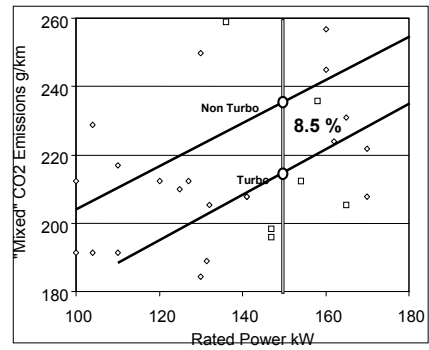
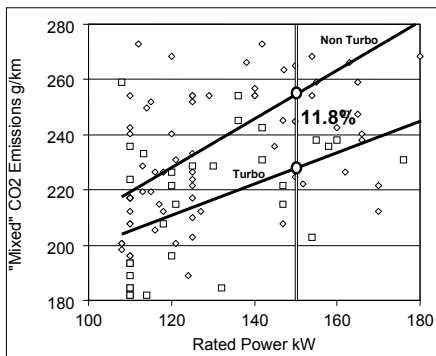
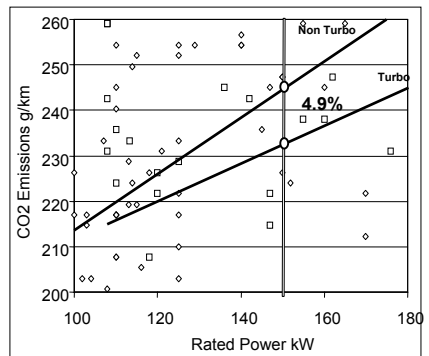
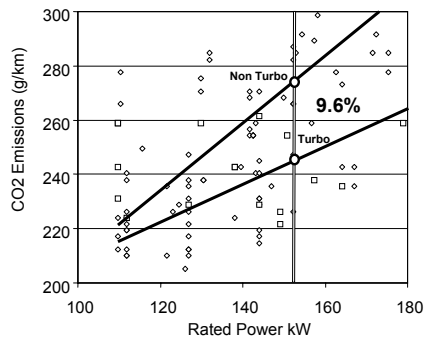
5 to 20% CO₂ Reduction

- All production engines/vehicles in family sedan range - sports cars excluded
- Manufacturer certification data from published sources
 - All data INCLUDED in mathematical linear fit
 - Graph display sized for visibility
 - Some data fell off the chart but is part of linear fit
- Hundreds of non-turbo and tens of turbocharged vehicles in the data base

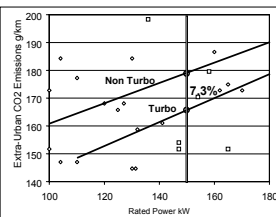
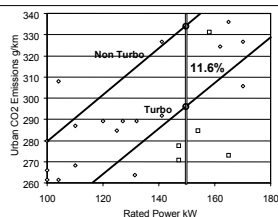
Benefits Measured over a Long Period and on Large Sample
Production Vehicles



Less CO₂ Emissions with Turbo Engines on All Model Years



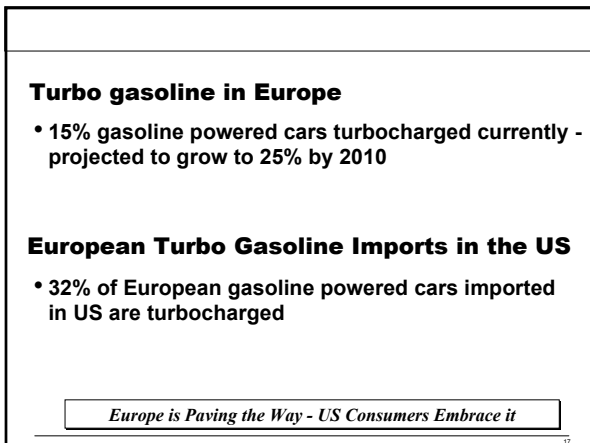
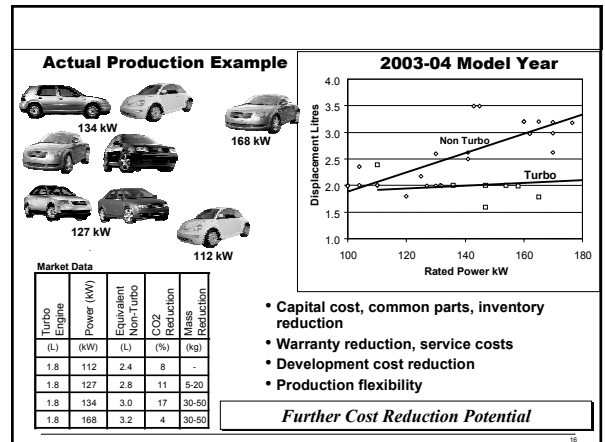
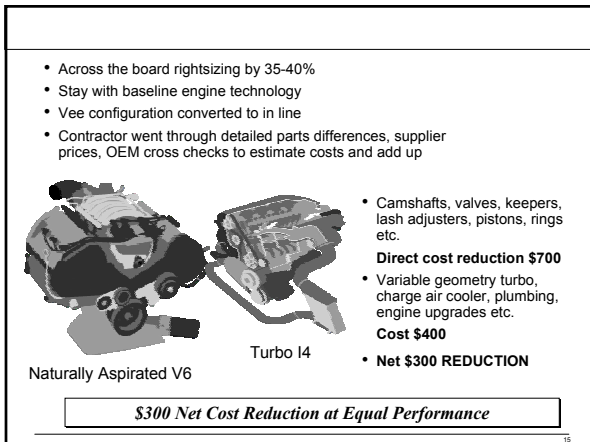
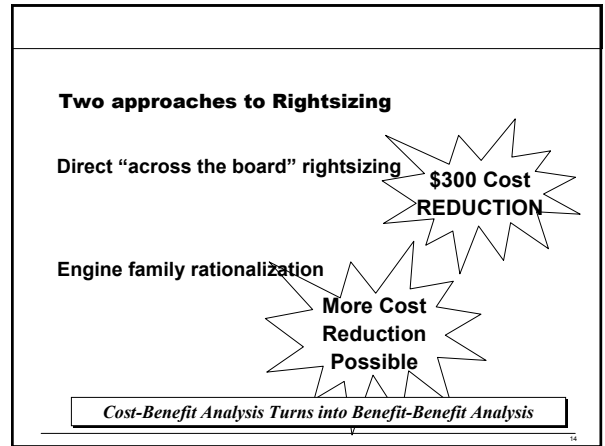
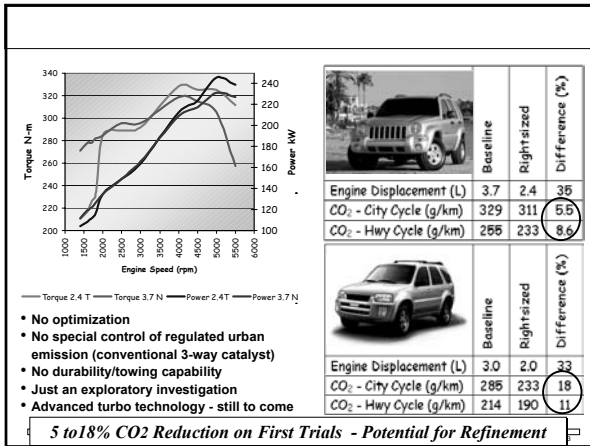
Urban & Extra-Urban Emissions

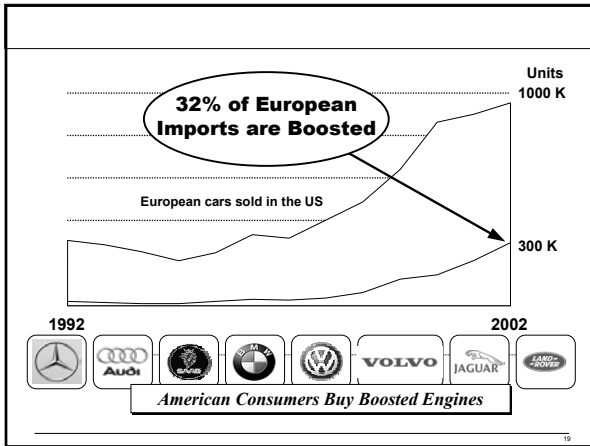


CO2 Reduction in Both Driving Cycles

Organization	Right-sizing (%)	CO2 Reduction	Reference	Remarks
AVL	29	15	SAE 2002-01-0236	Turbocharged, CBR, Miller Cycle Simulation
IFP	40	20	SAE 2003-01-0542	Stoichiometric DI, Engine Data - Vehicle Simulation
FEV	40	18	SAE 2001-01-3192 SAE 2002-01-1103	Vehicle Data, Variable Compr. Ratio Additional Benefits (9%).
Ricardo	30	21	SAE 2004-01-0036	Engine Data - Vehicle Simulation, Lean Boost DI

Common Denominator - Boosting/Right-sizing Methodical Development Gives 15-20% CO2 Reduction





Benefits/feasibility (% CO₂ Reduction)

- 15-20% reduction in emissions possible with proper development

Cost

- \$300 net cost reduction with simple rightsizing
- Further cost reduction with engine family rationalization

Customer Acceptance

- 32% "acceptance" already demonstrated in the US

Rightsizing / Turbocharging is a Proven & Available Solution

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